NERVOUS MECHANISMS, AND THEIR BEARINGS ON EDUCATION.

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I.

Our present state of existence is one in which we are, in every way, subject to limitations, some of the most stringent of them being so common that they are usually overlooked. Consider, for instance, on what feeble means we are dependent for all our information about things without us; we can know nothing except through the medium of our senses, that is, of organs (eyes, ears, &c.) of most delicate structure, easily disordered, and frequently faulty. A slight defect in the eye, and things are mis-shaped to us; another, and we lose colour; another, and we are blind; similarly with the ear. Thus, however great may be the powers of the mind, through the misfortune of being in a body without eyes or ears, it will be shut out from nine-tenths of the possible knowledge of things without; and in less extreme cases knowledge will be inaccurate through slight defects in these frail organs. While in this state of existence we are so bound up in our bodies that we can learn nothing but through their feeble means, and if those means fail us we are left in the dark. These are facts well known to all, and, it may be added, no one supposes that they imply anything about other states of existence; no one supposes that because we can now only see by means of eyes, it is thereby implied that in other states of existence (that of a disembodied spirit, for instance) there may not be other and greater powers than our sight.

But the above are only a small part of our total limitations. Not only are we dependent on bodily organs (the senses) for all our ideas, but we are equally dependent on a bodily organ (the brain) for all thoughts and feelings about those ideas; and, just as a defective eye will give us wrong information, a defective

brain will make us draw wrong conclusions, and, still worse, will make us have wrong feelings; and, unfortunately, defective brains are far more common and far more easily caused than defective eyes. This fact of our dependence on our brains is one with which we are very much less familiar than that of our dependence on our senses, but it is of far greater importance in many ways—in none more than in its bearing on education; for, just as the eye is palsied by no-use, spoiled by mis-use, or perfected by good use, so, but in a far greater degree, is the brain; indeed, there is hardly any comparison, for the varieties of form into which the brain may grow are innumerable, and the difference between their extremes practically infinite. Education is, in literal fact, the training of the growth of the brain, and the importance of realising this fact can hardly be overestimated. So long as it is supposed that education only deals with a mysterious mind, or spirit, too tenuous to be graced with permanent beauties or deformed by permanent scars, so long will its real power be overlooked; but it is very different when it is practically realised that education is the training of a bodily organ into permanent forms and conditions of growth. And this fact is realised by so few that it seems worth while to attempt to show, as far as can be done in these limits, the function of the brain as the organ of thinking and feeling.

Let it be remembered that in affirming that in our present state of existence we can only think or feel by means of our brains, nothing is inferred or implied about other states of existence, any more than in the case of seeing only with the eye, already alluded to; nor is there anything incompatible with any received form of faith, nor with the most spiritual conceptions. While in this body we can only see with eyes and think with brains; if our eyes fail, we lose sight—if our brains, we lose consciousness (as in a faint); but nothing is hereby implied as to the seeing, or thinking, or greater equivalent powers that may pertain to other states of existence.

In order to arrive at the conception of these highest functions of nervous structures it will be well to briefly consider the general nervous system, and some of its simpler functions first. The nervous system (as far as concerns our purpose) consists of the brain, the spinal cord, and the nerves; the brain occupies the skull; the spinal cord, about the thickness of the little finger, passes down from the brain and occupies a canal running along the backbone; the nerves are whitish cords of varying size passing out from the brain and spinal cord, some to terminate in special organs of sense, like the optic nerves to the eyes, and the auditory nerves to the ears, others branching and passing, some branches to the surface of the skin everywhere over the body, other branches to all the muscles. The surface of the brain to a depth of rather less than a quarter of an inch is of a grey colour, towards the base of the brain there are some masses of the same colour, the rest of the brain substance is white; a column of the grey matter runs down the middle of the spinal cord, and is surrounded by white matter. All of this nervous material is made of two elements, nerve-cells, and nerve-fibres; the nerve-cells are very small bodies, from 250 to 500 of them would lie in an inch of length; each cell has several rays or branches passing into fine filaments by which it is connected with nerve-fibres or more directly with other cells; the nerve-fibres are from $\frac{1}{12000}$ to $\frac{1}{2000}$ of an inch in diameter; they terminate either in nerve-cells, in muscles, or in organs of sense; the nerves are merely bundles of nerve-fibres; the white material of the brain and spinal cord consists of nerve-fibres; the grey matter in the brain and spinal cord consists chiefly of nerve-cells, with connecting fibres. The greatest collection of nerve-cells is that forming the grey matter of the surface of the brain, and the amount is greatly increased in the brains of the higher animals by the surface being thrown into numerous folds, called convolutions; these myriads of cells are connected by fibres with each other, and with the cells forming the masses of grey matter in the base of the brain; these connecting fibres make up the white matter of the substance of the brain; the collections of nerve-cells in the base of the brain are also, some of them, connected with the special organs of sense, others with the fibres ascending from the spinal cord. In the spinal cord we have the central column of grey matter consisting of cells; these cells are connected with each other; and with the cells in the base of the brain, by the fibres passing up to them; finally, some of the cord cells are connected with fibres passing out in the nerves to the muscles, others with fibres passing in from certain minute organs in the skin (the organs of the sense of touch).

The function of the nerve-fibres is a merely passive one, that of conducting nervous impulses; these impulses originate from the action of a nerve-cell, or from an impression made through an

organ of sense; for instance, the action of a nerve-cell in the spinal cord may send an impulse along a nerve-fibre passing to a portion of muscle, and cause the movement of the latter; or a spot of light falling on the eye may cause a nerve-impulse to pass along a fibre of the optic nerve to a cell in the base of the brain. The functions of the nerve-cells are various and must be considered in detail; the molecules, or particles, of which a nerve-cell is built up are in such an unstable condition that any stimulus readily excites them to change; this molecular change constitutes a nerve-cell action; it may be of very various degrees of violence; it exhausts the nerve-cell in proportion to its violence (and when exhausted the cell cannot act again until restored by nutrition from the blood); it affects the substance of the cell, and especially of young growing cells, so as to leave an impression on the cell, permanent in proportion to the violence of the action and the number of its repetitions. When a nerve-cell acts, impulses tend to pass off from it along its various connecting fibres; the force and number of these impulses depends on the violence of the cell action; if this is gentle there may be only a slight impulse passing off through the largest connecting fibre (the freest channel); if the action is violent it will overflow through the various connecting fibres in impulses increasing in force and number with the violence of the cell action.

The simplest function of a nerve-cell is that of causing muscular movement; this is the function of many of the cells in the spinal cord (motor cells); when one of these is excited to action an impulse passes out from it along a fibre leading to a portion of muscle, which is thus stimulated to contract; it is thus all movements are caused; to cause the contraction of any number of muscles very many cells would need to act.

It is evident that to execute any definite movement (such as the withdrawal of the foot quietly in a certain direction) the regulated and combined action of many muscles is required; this controlling influence is derived from certain groups of cells in the base of the brain, which are connected with the groups of motor cells in the spinal cord, and so combine their action. Certain other cells (sensory) in the spinal cord have the function of receiving impulses from the organs of touch in the skin; being thus excited to action, they send impulses along the fibres connecting them with the motor cells in the cord, which, being excited, in their turn send impulses to the muscles and cause movement ; in most cases the excitement of the sensory cells also sends impulses up to the controlling cells, and thus the movement induced is a definite and orderly one.

If we tickle the foot of a person whose spinal cord is injured, the foot will be withdrawn by an irregular wild jerk ; if there is no injury the foot will be quietly and steadily withdrawn (even in sleep) ; in the former case the excitement of the sensory cells caused by the impulse sent up from the tickled skin passed off to the motor cells, but could not, because of the injury, pass up to the controlling cells ; in the latter case both sets acted. Some other instructive points are here brought out. We know that if the tickled individual is awake he can prevent the foot from being withdrawn ; that is, the controlling cells can actually prevent the action of the motor cells from taking place ; there is, however, a limit to this inhibiting power. This example also illustrates the effect of a violent cell action. If the foot of a sleeping (or deeply thinking) person is tickled it is quietly withdrawn ; that is to say, the gentle skin irritation sends a gentle impulse to the sensory cells, which are gently excited, and send gentle impulses to a few motor cells ; but if the foot be suddenly burnt, the sensory cell action, excited by the powerful impulse from the severely irritated skin, will be so violent that it will overflow through many more connecting fibres, and almost every muscle in the body may be thrown into violent action, causing the person to spring vigorously away from the injury.

Let it be noticed that we have now considered examples of cell action amounting to the reception of impressions from the skin, and the consequent performance of orderly muscular movement, without yet taking any account of a thinking being at all, the actions considered being possible in a sleeping person ; not only is this so for the cells connected with the skin, but it is equally true for certain of the cells connected with all the senses. Impulses sent from the eyes or ears will similarly excite certain cells in the base of the brain to action (cells in the optic centre and auditory centre), and these will send impulses to controlling and motor cells, which by their action thus excited will cause orderly complex muscular movements. Thus we may have the most complicated movements, regulated by the controlling cells ; they, in their turn, stimulated by impulses coming from the various senses ; and no thinking being yet considered. Such are the movements performed by a frog, all of whose brain, except the base, has been removed, whose actions are so perfect that the mutilation might easily be overlooked ; such are the movements of a person walking in a crowded street, involved in such deep thought as to be utterly unconscious of the obstructions he is skilfully avoiding ; such, also, are the actions of a chick, who will, almost immediately after it has left the shell, perform such a complex accurate act as to peck at a moving insect. These actions are all of the class called reflex, being, even the most complex of them, merely the reflexions back to the muscles, through the different sets of nerve-cells, of the various impulses derived from the senses. They are also called sensory-motor movements.

In order to perform any orderly movement there must be a definite succession of contractions of certain muscles, each with definite force ; to produce this there must be a definite succession of certain cell actions of definite violence ; for instance, when the chick pecks at the insect there must be an inconceivably accurate succession of actions in certain of the chick's controlling cells ; the least error, such as the action of a wrong cell, or in wrong succession, or a wrong degree of any cell's action, and the accuracy of the movement would be completely lost. What is it that causes the cell actions to succeed one another in a definite course, both as regards order of cells excited and degree of excitement ? This orderly succession depends on the structure of the connecting fibres of the cells : each cell has several fibres of communication with others, when it is excited there will be a tendency to send impulses along all of these fibres, but the main impulse will pass along the freest channel (the largest fibre ? or best conducting ?) ; when the cell excitement is great it will overflow in impulses through more and more of the connecting fibres. But not only the freedom of the fibres of connection, but their arrangement, will determine the order of successive cell excitements. Suppose *a b c d e* to be nerve-cells (write the letters round a circle and draw lines for the connecting fibres) ; suppose *a* is connected with *c* and *d*, and *b* connected with *c* and *e* ; now, if *a* and *b* are simultaneously excited, it is evident that *c*, being connected with them both, will receive two impulses, and be more excited than *d* or *e*, which have each only one connection. This will suffice to show how the direction of the cell connections will help to determine the order of the succession of excitements. There would also be influence exercised by the nature of the cells themselves; an active vigorous cell would respond to a slighter impulse than a feebler cell. The course of a succession of cell-actions depends, then, on the nature of the cells and their connections, that is on the fixed structure of a portion of the nervous system. Now the further question arises, To what is this structure due? Why are the cells and their connections grown into one particular arrangement more than another? First, because of heredity: each individual is born with a definite structure of nervous tissue inherited from his progenitors; and, moreover, with a tendency towards a definite further growth, likewise inherited. For instance, the chick is born with a fixed nervous structure inherited from its race. The man, although probably born without the completed nervous structure which enables him to walk through a crowd, has inherited the tendency to grow into this arrangement.

But there is another factor in forming the growth of the nervous structure, and that is "training," or "education." The development of any part of the body depends on its use; this applies especially to young growing structures, and, probably, far more to nervous structures than to any other. When from any cause a new succession of nerve-cell actions is set up, there is a slight alteration in the constitution of the cells and connections, by which that particular succession is rendered easier; by repetition this is increased, and soon the cells and connections become so impressed that their growth is affected and the succession becomes a natural one, and will take place of itself when once started. There are two ways in which new successions of cell actions (let us call them "trains") may be set up; or rather there are two ways in which, when a train is started, the course which the existing nervous structure would force it to follow may be altered; first, by fresh impulses from the senses, causing fresh cell actions, and so modifying the existing train; this is really how very young animals of every kind are taught to perform new movements. The second method is one which can only be alluded to here; it will be more fully considered in the next paper; the individual, by voluntary attentive effort, can control and alter the trains of cell actions; this is how more advanced educated movements are acquired. When, either by impulses from the senses, or by

voluntary attentive effort, a new train has been a few times repeated, then the change alluded to above takes place in the nervous structure, and the train begins to run more and more easily; finally, the new growth is impressed on the nervous structure, and then the new train when once started will run of itself without needing either the fresh sense-impulses or the voluntary effort. As familiar examples of this take writing and piano-playing; here (as in most instances) there is a combination of both the sense-impulses and the voluntary effort directing each movement at first—that is, exciting the necessary succession of cells, but by-and-by the control is less and less needed, and at last we come to write quite independently of immediate control, and to play while earnestly talking about something else.

These examples illustrate some other important points. The wonderful precision of these trains of cell action; their permanence; and that when once fixed they are carried on most perfectly when least interfered with by attention. Notice that these are exactly what will of necessity result from these trains being due to a definite fixed growth of the cells and their connections. Handwriting illustrates at once the precision and permanence. Bear in mind what an exact succession of delicate cell actions must take place when we dash off a signature, and consider their precision—how that signature is always the same. Again, their permanence; try for years to correct a faulty letter, and when writing freely the old defective form will recur. As an instance of how these trains flow most freely, and the resulting movements are most swift and accurate when uninterfered with, take the case of some little tune learned on the piano in childhood by one who has since neglected all piano-playing; he may vainly try to direct his fingers on to the proper keys by attentive effort, but let him strike both hands boldly on the first notes, so as to start the old train of cell actions, and think about something else, and probably all the necessary movements of both hands will be correctly performed. This is, of course, equally the case with writing, but is less easily seen.

We may summarise what we have now arrived at as follows:—

The active elements in nervous matter are the nerve-cells.

The cells are connected with each other by fibres, through which their actions pass from one to another, setting up trains of successive cell actions.

The course a train of cell actions pursues (unless interfered with) is a definite one, depending on the vigour of the cells, and the size and variety of their connections.

The vigour of the cells and the size and variety of their connections, that is to say the grown structure of nervous matter, depend on two things, heredity and training.

Training is the establishing of new forms of growth in the nervous matter, by forcing the repetition of new trains of cell actions.

New trains of cell actions can be forced either by a succession of fresh impulses from the senses, or by a succession of voluntary attentive efforts.

The cells and their functions already considered are: sensory, to receive impulses from the senses and transmit them to other cells; motor, to receive impulses from other cells and transmit them to muscle, thus causing isolated movements; controlling cells, to receive impulses from sensory cells and transmit them to collections of motor cells, thus causing combined movements.

In a future paper the cells of higher function will be considered.

THE FÉSOLE CLUB PAPERS.

By W. G. Collingwood.

VIII.—THE SIGN OF THE SCALES.

"Divide and conquer" was the ancient rule of statecraft. We trot out our Pegasus team, the principles of composition, one at a time; and hope, if not to break them in immediately, at least to learn their points and something of the management they require. Last time we studied *Contrast*; this time it must be his yoke-fellow, *Symmetry*. In January* we must try another pair, *Unity* and *Variety*; in February the third pair, *Infinity* and *Principality*. And our year's work will be well ended if we can round it off with *Repose*.

Here parenthetically let me say that these are not exactly Mr. Ruskin's laws of composition, as stated in any of his books. He has given three lists of the laws of Beauty in Nature and in Art, none of which are offered as final codifications or as complete sets of rules for practical purposes.

(A) In "Modern Painters," Vol. II., he gives six chief laws of Beauty as seen in Nature:—

Infinity, Unity, Repose, Symmetry, Purity, Moderation.

These are stated to be *not* meant as exhausting the subject, but as illustrating analogies between Creation and its Creator.

(B) In "Elements of Drawing" there are nine laws of composition, that is to say, the conditions of Beauty in Art; these also being offered not as exhaustive, but merely as useful reminders:—

Principality, Repetition, Continuity, Curvature, Radiation, Contrast, Interchange, Consistency, Harmony.

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* There will be no Fésole Paper in the December (Christmas) number of the *Parents' Review*. Members are requested to choose their own subjects, and to send in drawings by New Year's Day.